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Remediation Strategies for CO_2 Gas Leakage Plumes in the Vadose Zone

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Carbon dioxide (CO_2) stored in deep geologic formations may leak unexpectedly upward from the storage reservoir to the shallow subsurface through abandoned wells or through natural fast-flow paths. Upon arriving at the watertable, a large CO_2 leakage flux will form a dense gas plume in the vadose zone and seep out of the ground. In the shallow subsurface, CO_2 is a potential risk to health, safety, and the environment. We have investigated different strategies, including both passive and active methods, for the remediation of CO_2 leakage plumes in the vadose zone. Numerical simulations were performed using a special module of the TOUGH2 simulator that models flow and transport of CO_2-air mixtures. As a general measure of the CO_2 removal rate, we defined the half-life of the CO_2 plume as the time required for one-half of the initial CO_2 mass to be removed from the domain. This rate for different scenarios was compared to determine the effectiveness of each method. Natural barometric pumping increases the

CO_2 seepage flux and thereby increases the removal rate of CO_2 relative to passive diffusion (i.e., no barometric pumping). The half-life of a CO_2 plume is generally shorter for thinner vadose zones, unless a significant amount of CO_2 mass is held in the capillary fringe, in which case the half-life increases because of the slow CO_2 gas transport away from regions of high water saturation. Active gas pumping from extraction wells is a very effective remediation strategy. Horizontal wells increase the rate of removal, as does the use of an impermeable surface barrier to prevent inflow of air through the top of the system. In general, passive and active strategies can be used to remediate CO_2 leakage plumes in the vadose zone.